MARINE OPTION PROGRAM DATA ACQUISITION PROJECT:

HONOLUA BAY, MAUI

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Principal Author: Leonard Torricer

Associate Authors:

Geoffrey Akita
Guy A. Anzai
Lisa Boucher
Richard Fantine
Tad Kobayashi
Gordon Muraoka
Holly Price
Steven Takenaka

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I. INTRODUCTION

At present, Honolua Bay is zoned as a conservation district. The Maui Land and Pineapple Company, which owns the terrain around the bay has commissioned several reports relating to possible development of the area and has recommended it for consideration as a marine conservation district (Kitahata and McCreary, 1975). Various studies and reports by private firms and government agencies support the upgrade in status to a State marine life conservation district. Among the surveys conducted are those by Environmental Consultants, Inc. (1974), Belt Collins and Associates (1974), Taylor (1975), and Kitahata and MCreary (1975).

To date no extensive examination of the Honolua marine fauna and flora had been done, although three separate fish surveys by ECI (1974), Gaffney (1975), and Taylor (1975) produced preliminary information. The ECI report does not go into detail about the type of fish fauna found at Honolua Bay other than presence or absence. Accompanying this report is a coral census, which provides some data on coral distribution in the bay. Gaffney conducted an informal fish survey without the benefit of any standardized procedure. According to Kitahata and McCreary (1975), Gaffney's dives extended to the mouth of the bay and to the areas of the reef. Consequently it is probable that he counted a number of species not found in the sheltered shoreward waters. Taylor noted that his survey was preliminary in nature, and more stations and replications would be required for an accurate baseline assessment of the Honolua fish fauna. No marine algae study had been done in the bay.

Nine Marine Option Program (MOP) students completed fish, coral, and algae surveys of Honolua Bay during the period of June 20-25, 1976. The study provided baseline data for future studies, established permanent monitoring stations, and increased the students' knowledge of Hawaiian reef life and ecology. The raw data collected by these students is stored at the Hawaii Coastal Zone Data Bank (HCZDB) located on the University of Hawaii at Manoa campus. It is available to the public.

Honolua Bay, the only sheltered bay on Maui with a structural reef (Kitahata and McCreary, 1975), is located on the northwest coast of Maui about 20.9km north of Lahaina Harbor. Immediate access to the bay from Honoapiilani Highway is accomplished by a 0.48km unimproved, sloping, dirt road, which crosses over the Honolua stream bed. The study site covers an area of 13,000 square meters, which encompasses the body of water landward of an arbitrary boundary line drawn from the tip of the promontory between Honolua and Makuleia Bays to a point on the opposite side of the bay. (See Figure 1). According to the USGS map of Honolua Bay (N2057.5 - W1563517.5, 1956) the approximate geographic coordinates for the northern end are 21°0'17"N by 156°38'37"W, and the southern end are 21°01'02"N by 156°28'48"W The boundary line is about 0.6 km in length and runs approximately 150° magnetic from the promontory.

The shoreline of Honolua Bay is mainly a boulder beach, except for three sections. On the southern shore, a small cliff drops directly into the bay. A short, coral rubble beach is situated on the northern shore and a dark sand beach stretches along the southeastern shore. (See Fig. 2.) This beach is bordered by a 50-year-old, concrete boat ramp on the northern end and by the mouth of Honolua Stream on the southern perimeter. (See Fig. 2 and 3.) From the Honolua watersheds the stream delivers approximately 8.33 million liters of fresh water daily into the bay (Environmental Consultants, Inc., 1974).

The study site consisted of three distinct regions. (See Fig. 1). Two fringing reefs spread out into the bay from the northern and southern shorelines.

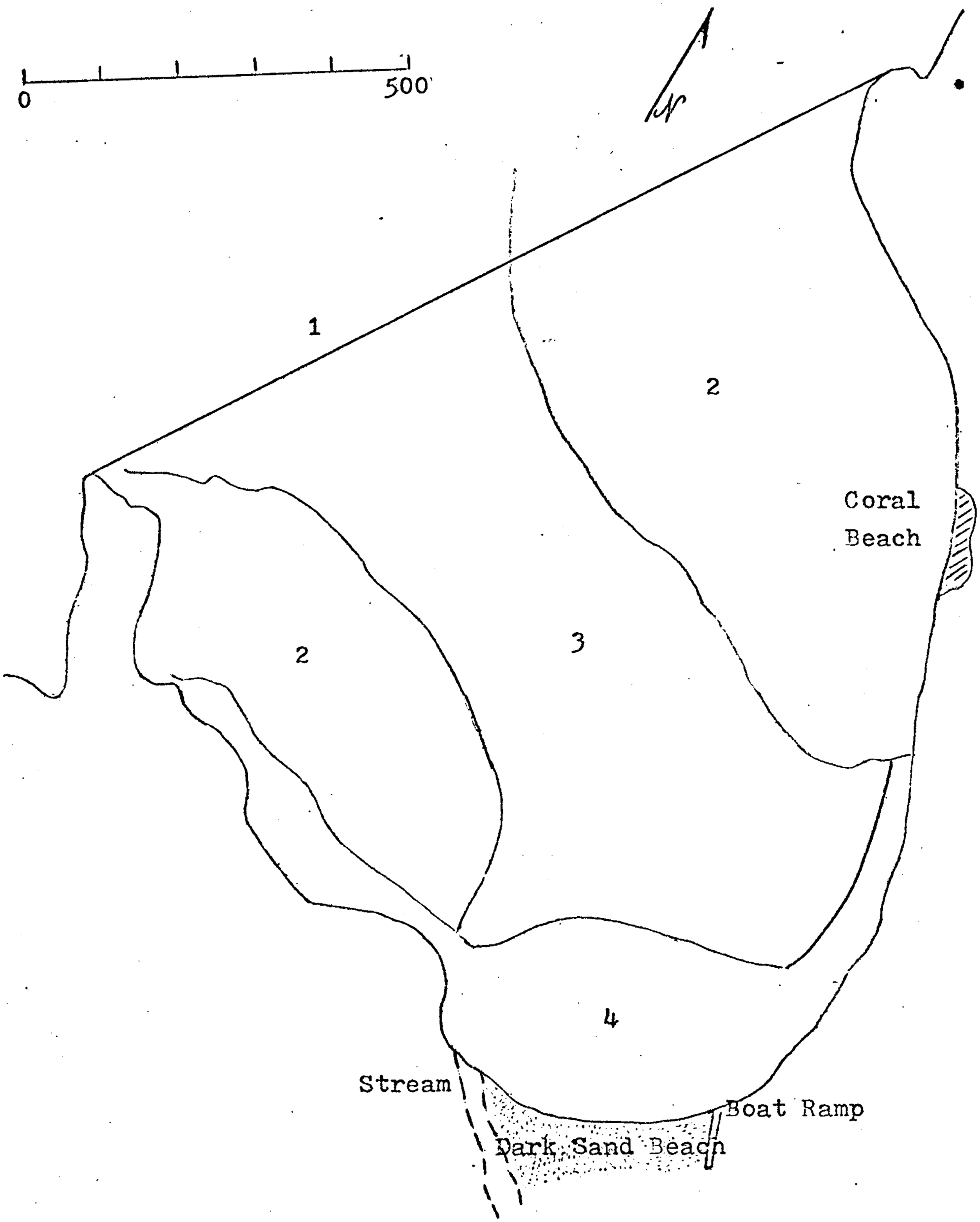


Fig. 1 Substrate of Honolua Bay, Maui, (adapted from Kitahata and McCreary, 1975); 1 = boundary line, 2 = fringing reefs and flats, 3 = sand/silt channel, 4 = sand/silt and boulder bottom.

Fig. 2 The dark sand beach along the back of Honolua Bay. The area immediately in front of the shrubline in the background is the mouth of Honolua Stream. The promontory is "Crescent Point." Note the stillness of the bay.

Fig. 3 The concrete boat ramp which marks the boundary between the dark sand beach along the back of the bay, and the boulder shoreline along the northern shoreline. The hump-like cliff in the background is "Middle Point."

(See Fig. 4.) A sand/silt channel between the fringing reefs, which runs up the central axis of the bay, is approximately 100m wide at the center of the bay. A sand/silt and boulder bottom circumscribes the inshore region of the bay. (See Fig. 5 and 6.)

II. MATERIALS AND METHODS

A. Site Selection

Sites for transects were located by selecting three suitable land marks which were then sighted from the water before the onset of each transect with a hand held compass giving the landmark's bearing in degrees. These three land marks were then located on a chart and a line scribed from each in the specified direction. The approximate start of each transect on the map was placed central to the intersection of the scribed lines. All transects ran parallel to shore and at an approximately constant depth. Sites were selected rather than randomly chosen to adequately sample the specified areas in the limited time available.

B. Fish

A modification of the visual census method utilized by Brock (1974), Odum and Odum (1955), Bardach (1959), and McVey (1970) was employed at all locations. Divers, equipped with either SCUBA or snorkel gear, worked in teams of four, consisting of one line "roller", two "counters", and one "safety diver". (See Fig. 7.) Counters followed a 100 meter plastic line laid out by the line roller. Each counter was responsible for: (1) identifying species; (2) estimating the number of individuals of each species; (3) estimating the standard length (tip of snout to middle of caudal peduncle) of each individual in an area 5m wide and within 2m from the bottom, adjacent to the transect line. The combined area covered by both divers equaled 10m by 100m or $1000m^2$. Upon completion of "Station A" (origin to the end of 100m) counters exchanged lanes and repeated

Fig. 4 The northern reef flat. The calmness of the bay and the shallowness of the water on the reef make the reef easily visible. Photograph taken atop "Middle Point."

Fig. 5 The boulder inshore habitat along the northern shoreline.

Fig. 6 The boulder inshore habitat along the southern shoreline. Taken from atop the cliff inside of "Crescent Point."

Fig. 7 The typical diamond-shaped formation of the fish transect method. The line roller leads the group with the two fish counters following behind on each side of the transect line, and the safety diver bringing up the rear. Line roller Lisa Boucher; fish counters Tad Kobayashi and Leonard Torricer; safety diver Holly Price.

the previous procedure back along the same line (Station B).

These fish stations are isolated from one another temporally, not spatially. Usually, it took between 15 and 20 minutes to travel one way down the length of the 100m transect line. Thus, the second fish count along the transect line would commence 15 to 20 minutes later than the first. Approximately 90 minutes elapsed between fish transects of different sites to allow the coral and algae team to complete the coral and algae transects, and to locate the next site to be surveyed.

In addition, points of interest and species of fishes outside of transect areas were noted on vinyl underwater slates and later transcribed to data sheets for processing and storage. Collected data were processed via several programs devised by Dennis Kam of the Hawaii Coastal Zone Data Bank (HCZDB). The HCZDB printout included number of species found at each particular location, number of individuals per species, biomass, standard length, frequency of occurrence (number of stations a particular species appeared at, divided by the total number of stations conducted), and presence/absence of species on transects.

The species of fishes were categorized by feeding habits based on feeding studies done by Hobson (1974) at Kona, Hawaii. The three categories were: (1) herbivores--strictly algal and detritus feeders; (2) omnivores--opportunistic feeders on both plant and animal matter; and (3) carnivores--feeders on animal matter, including coral, plankton, and other fishes.

Dominant groups of fishes were determined by high frequency of occurrence ($\geq$0.615) rather than high biomass or large numbers of individuals since itinerant species occurring in large schools on a few transects would have large biomass and numbers, yet would not truly indicate the commonness of that species.

Fishes were grouped by occurrence over similar substrates in an effort to determine preferred habitat. Habitats included steep slopes with abrupt dropoffs;

a gentler, sloping bottom with rich coral cover; areas of boulders and ledges; and areas with sparse coral cover on a silt or sand bottom.

It must be noted that information collected by the visual census method is only a rough estimate and at best a conservative estimate of the total population present. Discrepancies between the actual population and data collected can be attributed to: (1) the several families of nocturnal fishes, such as apogonids ('upapalus), holocentrids (squirrelfishes), and priacanthids ('aweoweos), which retreat into cracks and crevices during the day (Gosline and Brock, 1960; Hobson, 1968) making sampling difficult; (2) the behavior and relative abundance of certain crepuscular species which occur during dawn and dusk periods (Hobson, 1965; 1968) and would be overlooked by the visual transects run at other times; and (3) observers "spooking" fishes out of the area under study.

Other methods of sampling such as fish poisoning (Randall, 1963) and use of explosives (Talbot, 1965) were not considered. Although possibly yielding a more complete count, these methods would be detrimental to the population sampled.

C. Substrate

The coral/invertebrate and algae surveys were done in conjunction with the fish surveys at each designated site to allow for a correlation of the three.

For each transect, ten random numbers (0-100) were picked from a random numbers table and subsequently matched to the meter number on the 100m transect line. For example, if the number 17 was picked, that would indicate one sampling site on the 17 meter mark.

At each of the 10 sampling sites along the line, a modified photographic method devised by Dr. S. Arthur Reed and a visual field identification were employed. The photographic method utilized a Nikonos camera equipped with a 35mm lens mounted on a 1.3m high aluminum stand. Light readings were taken at the beginning of each transect and the camera was adjusted accordingly. (See Fig. 8.) Problems occurred with this method when the depth of the water over the reef flat was less than four feet (See Fig. 9), and when one of the points on the transect was located in an area without a flat bottom for the stand to rest upon (See Fig. 10).

A plastic 5cm by 5cm card marked with the area and sample number was placed on the substrate sample to insure correct identification of the photograph. The camera photographed a 0.5m by 0.8m section for a total area of $4m^2$ along the entire transect. Visual field identification was conducted at the same time, with samples of unknown species retrieved for later identification. Coral species and other types of substrate were recorded on plastic slates. This visual method insured some data in the event of film failure and was used as an aid to proper taxonomic identification when slides were reviewed.

The substrate was divided into six categories and defined as: (1) hard basalt bottom; (2) rubble (loose, dead coral); (3) sand; (4) silt and mud; (5) algal mat and; (6) live coral.

The slides were projected life-sized onto a screen with $10cm^2$ grids and the percent cover of each category was estimated. For example, if 15 grids were occupied by three species of coral and the remaining 10 by rubble, it could be estimated that 60 percent of that particular site was live coral cover and 40 percent rubble. The live coral could be broken down into percent cover by species using the same method.

Frequency of occurrence and similarity indices were also obtained by the Hawaii Coastal Zone Data Bank. Frequency of occurrence is the number of transects on which a particular type of substrate or species appears, divided by the total number of transects conducted. Similarity index indicates how similar (by

Fig. 8 The coral/invertebrate and algae team at work. Gordon Muraoka in the foreground enumerated the substrate types. Geoffrey Akita with the grid used to estimate algae cover and Steven Takenaka handling the camera stand utilized for substrate photograph.

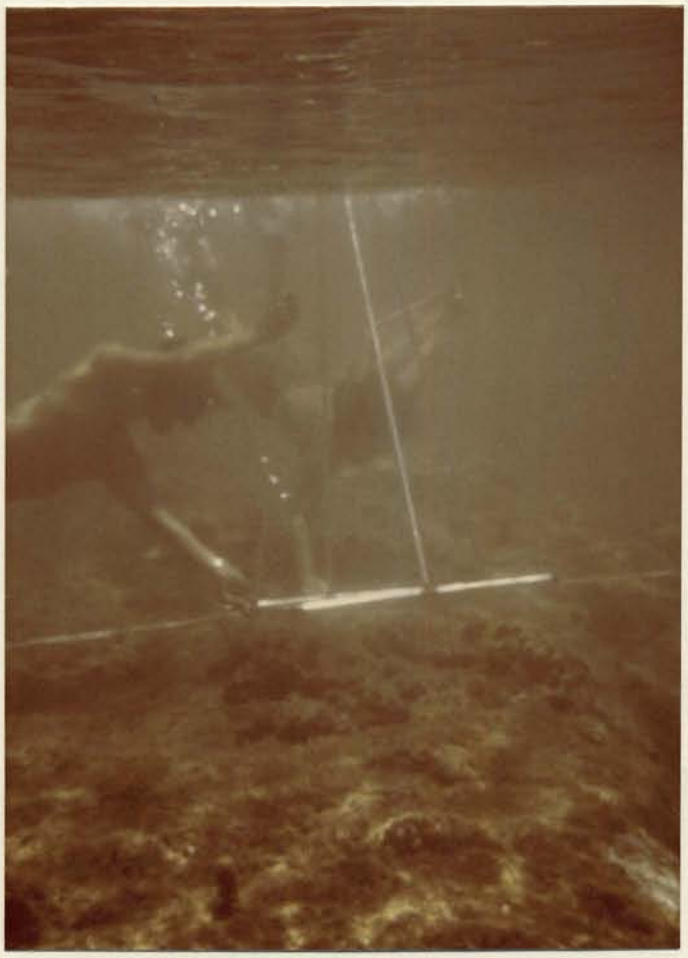


Fig. 9 A problem encountered by the coral/invertebrate team is the water depth above the reef flat. If the depth was less than four feet, the camera stand would be of no use because it is four-feet high. At a few transects, the water depth almost went below four feet.

Fig. 10 Another problem encountered by the coral/invertebrate team with the camera stand was the unevenness of the bottom. At certain sites the area photographed was almost perpendicular to the bottom.

percent of individual species) one transect is to another, by the value obtained from the Sorensen quotient (Sorensen, 1948).

$$\text{Where: Similarity Index} = 2 \times \frac{\sum \min (a_1, b_1)}{A + B}$$

A = Total number of individuals at Transect A

B = Total number of individuals at Transect B

a_1= Number of individuals of species 1 at Transect A

b_1= Number of individuals of species 1 at Transect B

Therefore, the higher the value between transects, the more alike they are.

D. Algae

The algae survey was conducted using SCUBA and a modified point-quadrat method. A $50cm^2$ quadrat divided by a 10cm grid was placed at five points (every other point of the invertebrate team's ten random points) along a 100m transect line. At each point the dominant algae occupying each of the 25 $10cm^2$ squares of the gridded quadrat was identified and mapped on a plastic slate bearing a scaled down grid. (See Fig. 8.) Visual estimates further divided an individual $10cm^2$ square into: (1) two parts, indicating 50% cover between two genera; or (2) three parts, indicating 33% cover between three genera; or (3) four parts indicating 25% cover between four genera (rarely done).

Unidentified, dominant algae occurring in the transect were collected and recorded in code to provide a basis for further identification upon return from the field work. In the absence of algal cover, the type of substrate beneath each $10cm^2$ square was recorded. To standardize terms, the invertebrate team's definitions of specific substrate were followed, except for "rubble," which included live coral in this study.

Comments including genera of algae observed on or near the transect line but not recorded on the transect, interesting features of the substrate, physical factors, and unusual events occurring during the transect were also noted. Transcription of the raw data from the plastic transect slate took place immediately after each transect to avoid transcription error.

Values corresponding to the proportion of $10cm^2$ squares each genus occupied per transect were tabulated by the Hawaii Coastal Zone Data Bank. The area surveyed per transect amounted to $1.25m^2$. Each survey area was analyzed for frequency (the number of transects a genus appeared in, divided by the total number of transects performed) and percent cover (the number of $10cm^2$ squares occupied by a genus, divided by the total number of squares). Algae with a frequency of ≥ 0.50 or appearing on at least half the transects were considered dominant forms. Tests of Sorensen's similarity quotient were also run between transects.

III. RESULTS

A. Algae

Work at Honolua Bay yielded 16 completed transects, 13 within the ellipse of the bay, one outside the ellipse, and two outside Honolua Bay proper. (See Fig. 11 and Table 1.) The transects ranged between 1.2m and 13.7m in depth and had an average deviation in depth per transect of 2.5m.

Honolua Bay displays diverse benthic flora. Thirty-one algal species were observed: 28 "known " two "unidentified" red algae, and one "unknown," along with three types of substrate--rubble, sand, and silt. (See Table 2 for a complete listing of species.) Many thalli of _Turbinaria_ sp. and _Galaxaura_ sp. were seen and noted on the basalt shelves yet these genera appeared relatively few times on the transects.

The dominant genera (frequency ≥ 0.5) and their corresponding percent cover for $20m^2$ total transected area were coralline red algae, filamentous red algae, and _Amansia_ sp., another red alga.

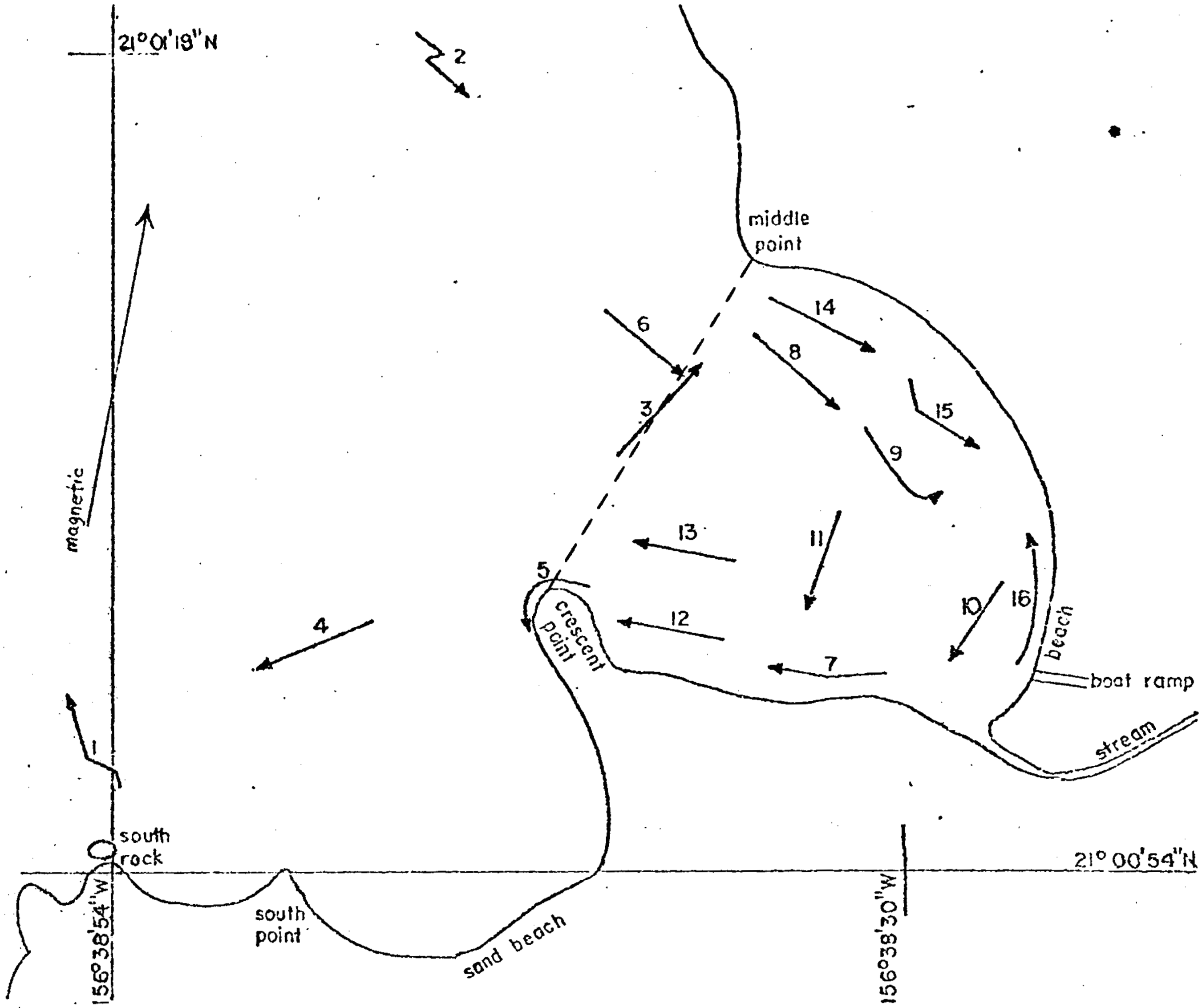


Fig. 11 Mercator projection chart of Honolua Bay, Maui, with the approximate locations of the 16 monitoring sites, (Scale 1:8,000 and 1" of latitude = 101.268 feet)*.

*Capt. Bill Austin, master of the Machias, constructed the chart by transferring offsets from USGS chart no. 4130. Transferring from such a small scale chart results in a coastline that does not show the definition that would be achieved by using an aerial photograph, or a larger scale chart. "Middle Point," the boat ramp, "Crescent Point," "South Point," and "South Rock" are arbitrary names given to areas used as triangulation points for the location of the monitoring stations. Stations 1, 2, and 4 are situated outside the proposed marine conservation district. June 18, 1976.

TABLE 1

Coordinates, depth and visibility of the 16 monitoring sites at Honolua Bay, Maui

Site	Latitude	Longitude	Direction of Transect	Depth (meters)	Horizontal Visibility (meters)
1	21°00'56" N	156°38'54" W	328½°T	6.1 - 10.1	6.1 - 12.2
2	21°01'19½"N	156°38'46½"W	132 °T	6.1 - 9.1	9.1 - 12.2
3	21°01'06" N	156°38'39" W	41 °T	4.6 - 13.7	9.1
4	21°01'01½"N	156°38'46½"W	47 °T	10.7	15.2
5	21°01'03" N	156°38'39½"W	follows pt. from E-W around Point	9.1	30.5
6	21°01'10½"N	156°38'39" W	130 °T	4.6 - 6.1	21.3 - 24.4
7	21°01'00" N	156°38'30" W	275 °T	1.5 - 3.0	15.2
8	21°01'10" N	156°38'34" W	132 °T	1.8 - 2.4	18.3
9	21°01'07" N	156°38'31" W	132 °T	6.1	12.2
10	21°01'04½"N	156°38'27" W	209 °T	2.7 - 3.0	9.1
11	21°01'05" N	156°38'32" W	201 °T	9.1	9.1
12	21°01'01" N	156°38'35" W	281½°T	3.0 - 7.6	22.9
13	21°01'03" N	156°38'35" W	282 °T	1.8 - 7.6	24.4
14	21°01'11" N	156°38'34" W	116 °T	1.2 - 1.5	9.1
15	21°01'08" N	156°38'30" W	118½°T	1.2 - 6.1	6.1 - 12.2
16	21°01'00½"N	156°38'26" W	07½°T	1.8 - 2.4	12.2

TABLE 2

Algae species at Honolua Bay, Maui, with frequency and percent cover for $20m^2$

	Frequency	Percent cover
Phylum Cyanophyta		
Filamentous--Genus undetermined	0.125	<1
Symploca sp.	0.063	<1
Phylum Chlorophyta		
Filamentous--Genus undetermined	0.438	3
Enteromorpha sp.	0.125	<1
Dictyospheria cavernosa	0.313	1
Dictyospheria versluysii	0.188	<1
Microdictyon sp	0.188	<1
Udotea sp.	0.125	<1
Bryopsis sp.	0.125	<1
Codium sp.	0.063	<1
Halimeda sp.	0.125	<1
Phylum Phaeophyta		
Encrusting--Genus undetermined	0.313	1
Filamentous--Genus undetermined	0.188	1
Ralfsia sp.	0.188	<1
Dictyota sp.	0.063	<1
Lobophora sp.	0.063	<1
Turbinaria sp.	0.188	<1
Phylum Rhodophyta		
Genus undetermined from Transect 7	0.125	<1
Encrusting--Genus undetermined	0.188	<1
Filamentous--Genus undetermined	0.750	11
Family Corallinaceae-Genus undetermined	0.688	14
Galaxaura sp.	0.438	1
Pterocladia sp.	0.125	2
Amphiroa sp.	0.625	8
Jania sp.	0.875	22
Haloplegma sp.	0.063	<1
Spyridia sp.	0.063	<1
Amansia sp.	0.563	5
Tolypiocladia sp.	0.188	1
Phylum undetermined		
Unidentified from Transect 1	0.063	<1
Unknown	0.138	1
Substrate		
Rubble	0.063	<1
Sand	0.375	14
Silt	0.375	13

TABLE 3

Dominant algae (frequency$\gtrsim$0.5) and corresponding percent cover observed at Honolua Bay, Maui.

Genus	Frequency	Percent cover
Jania sp.	0.875	23
Filamentous Rhodophyta	0.750	11
Family Corallinaceae	0.688	14
Amphiroa sp.	0.625	8
Amansia sp.	0.563	5

Three of the dominant genera, *Jania* sp., *Amphiroa* sp., and filamentous Rhodophyta, were almost always observed epithytic on each other, forming tufts or mats covering and filling pockets in the hard substrate or filling the space between fingers of corals. Filamentous reds were often observed in light growth on the heads of live corals. *Amansia* sp. also seemed to form tufts or mats on the same substrates. Crustose members of the family Corallinaceae formed encrustations over the boulders near shore. Often *Jania* sp., *Amphiroa* sp., filamentous Rhodophyta, or mats of all three were observed growing on the encrustations.

B. Substrate

The transects done in Honolua Bay showed a large number of coral species and a variety of substrate types. Six bottom types were reported in the 16 transects done in and around the bay area. (See Table 4.) In the live coral category, 13 coral species were represented. (See Table 5.)

Along the fringing basalt ledges where coral growth occurred coverage up to 36.4 percent with a diversity of up to 12 species in some areas was found. The area around the boat ramp, near the mouth of Honolua Stream, is covered with a fine terrigenous silt that extends outward into the channel. Little coral cover was seen in this region, a total of 1.2 to 6.4 percent coral cover was recorded (see Table 6) with a diversity of 3 to 7 species (transects 10, 11, and 16).

TABLE 4

Substrate types by transect at Honolua Bay, Maui.

Transect	Hard Basalt Bottom (%)	Rubble (%)	Sand (%)	Silt/Mud (%)	Algal Mat (%)	Live Coral (%)
1	0.0	3.2	6.1	0.0	60.9	29.8
2	0.0	10.6	1.0	0.0	58.2	30.2
3	0.0	0.0	0.0	44.9	30.6	24.5
4	0.0	0.0	100.0	0.0	0.0	0.0
5	5.0	2.0	45.0	2.0	38.9	7.1
6	0.0	0.0	0.5	0.0	76.8	22.7
7	34.7	0.0	15.0	1.5	39.3	9.5
8	0.0	0.0	0.0	1.5	77.6	20.9
9	0.0	0.4	43.5	19.8	5.5	30.8
10	0.0	0.0	0.0	93.6	0.0	6.4
11	0.0	0.0	0.0	98.8	0.0	1.2
12	1.0	0.0	0.0	3.0	61.3	34.7
13	0.0	0.0	7.5	12.5	43.4	36.6
14	0.0	0.0	0.0	2.5	93.9	3.6
15	0.0	0.0	68.1	0.0	16.0	15.9
16	0.0	0.0	0.0	94.3	4.4	1.3
Mean Percentage	2.5	1.0	17.9	23.4	38.0	17.2

TABLE 5

Abundance and distribution of corals at Honolua Bay

Species	Frequency	% of Total Live Corals
Porites lobata	0.938	36.6
Montipora verrucosa	0.875	15.0
Porites compressa	0.563	14.1
Montipora flabellata	0.500	10.9
Montipora verrilli	0.750	7.0
Pocillopora meandrina	0.750	5.3
Montipora patula	0.500	4.4
Cyphastrea ocellina	0.750	2.9
Pavona varians	0.438	1.4
Leptastrea bottae	0.438	1.3
Pocillopora damicornis	0.375	0.4
Pavona irregularis	0.188	0.4
Pavona explanulata	0.188	0.3

TABLE 6

Percent cover and number of coral species at each site

Site	Coral cover (%)	Number of Coral Species
1	29.8	9
2	30.2	7
3	24.5	9
4	0.0	0
5	7.1	6
6	22.7	11
7	9.5	9
8	20.9	12
9	30.8	7
10	6.4	7
11	1.2	3
12	34.7	9
13	36.4	10
14	3.6	6
15	15.9	6
16	1.3	5

On the southern portion of the bay's reef, the number of species and coral abundance increased near "Crescent Point." (See Fig. 12.) On transects 12 and 13, coral cover was recorded at 34.7 percent and 36.4 percent with a diversity of 9 and 10 species, respectively.

The nothern reef extending to "Middle Point" showed less coral cover but a higher diversity in some areas. Transects 3 and 9 both showed somewhat higher coral cover (24.5 percent and 30.8 percent) for this area, but somewhat lower diversity (7 to 9 species). At transects 6 and 8, the coral cover remained at 22.7 percent and 20.9 percent but with a higher diversity of 11 and 12 species, respectively. A Sorensen's similarity index was calculated between all pairs of the transects (see Table 7).

Corals most abundant in the Bay were *Porites lobata*, *Montipora verrucosa*, and *Porites compressa*, occurring at frequencies of 0.938, 0.875, and 0.563, respectively. (See Table 5). Of the total area surveyed, 17.2 percent was live corals with a diversity of 13 species.

The non-coral substrate of the bay covered 82.8 percent of the area surveyed and consisted of five bottom types. A large portion of the area was algal mat, silt, and sand with a large percentage of hard bottom occurring on transect number 7. (See Table 4.)

C. Fish

A total of 6,123 individual fish (mean = 236 per transect) were counted along the 26 stations. This ranged from a high of 1,774 fishes at station 3 to a low of 14 fishes at station 11. Of the total, 5,698 fishes were identified to species, while the other 425 fishes could only be classified to family (see Appendix 1). A mean of 22 species per transect was encountered, with station 3 containing the highest diversity (41 species), and station 11 the lowest diversity (5 species). The observed fish population consisted of 76 species representing 44 genera in

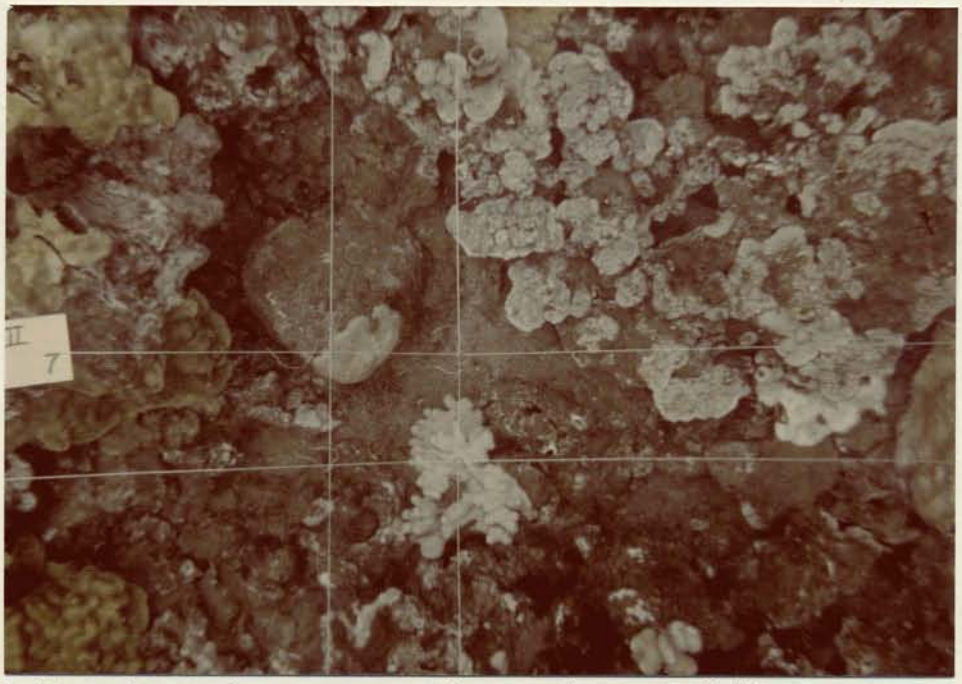


Fig. 12 Coral diversity and cover over the southern reef flat.

TABLE 7

Honolua Bay, Maui

Similarities between coral transects

Transect Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000															
2	0.847	1.000														
3	0.438	0.433	1.000													
4	0.061	0.010	0.0	1.000												
5	0.536	0.489	0.365	0.450	1.000											
6	0.797	0.761	0.451	0.005	0.449	1.000										
7	0.500	0.430	0.384	0.150	0.624	0.466	1.000									
8	0.799	0.753	0.450	0.0	0.442	0.933	0.445	1.000								
9	0.282	0.220	0.433	0.435	0.550	0.205	0.248	0.230	1.000							
10	0.054	0.059	0.489	0.0	0.061	0.060	0.045	0.062	0.243	1.000						
11	0.011	0.011	0.460	0.0	0.030	0.011	0.027	0.026	0.209	0.948	1.000					
12	0.809	0.769	0.479	0.0	0.458	0.798	0.500	0.809	0.226	0.077	0.042	1.000				
13	0.624	0.539	0.579	0.075	0.531	0.543	0.553	0.532	0.438	0.182	0.136	0.553	1.000			
14	0.639	0.605	0.362	0.0	0.432	0.801	0.422	0.825	0.103	0.043	0.030	0.668	0.479	1.000		
15	0.268	0.212	0.265	0.681	0.617	0.198	0.334	0.217	0.615	0.025	0.007	0.199	0.394	0.162	1.000	
16	0.051	0.051	0.500	0.0	0.071	0.051	0.067	0.066	0.249	0.944	0.949	0.082	0.176	0.072	0.048	1.000

18 families*. With the fish species identified on the three previous studies, the total fish species noted to date in Honolua Bay stands at 95.

The most common fish in the bay was the labrid Thalassoma duperreyi (Hinalea lauwili), with a frequency of 1.000 (See Table 8.) It was also the most abundant species in the study area with 821 members (about 11.8 percent of the population). The most frequently seen fishes (frequency $\geq$ 0.615) were members of the following families: Acanthuridae (surgeonfish), Balistidae (trigger- and filefish), Chaetodontidae (butterflyfish), Labridae (wrasses), Mullidae (goatfish), Pomacentridae (damselfish), and Tetraodontidae (puffers or balloonfish).

Honolua Bay was divided into three major habitats: boulder, reef flat, and reef face. (See Fig. 6, 13, 14, and 15.) The reef flat habitat had the largest number of fish with 43.4 percent (2,657 fishes) of the total (see Table 9). This was followed closely by the reef face habitat with 41.9 percent (2,567 fishes). The boulder habitat contained 14.7 percent (899 fishes). When compared to the other habitats, the boulder habitat fish population consisted of larger numbers of juveniles from the species Acanthurus triostegus (manini), Chromis ovalis, Chromis vanderbilti, and Parupeneus porphyreus (kumu).

A relative abundance index of the fishes in the habitats was calculated. The relative abundance of a species is the percentage that species represented of all fishes (individuals) counted along all transect lines in that habitat (after Hobson, 1974). Pomacentrids head the list in two of the habitats: Chromis leucurus in the reef face habitat, and Eupomacentrus fasciolatus in the boulder habitat (see Table 9). A labrid, Thalassoma duperreyi was most abundant on the reef flat. The only species in the top five of all three habitats are Eupomacentrus fasciolatus and Thalassoma duperreyi.

*The family Scaridae (parrotfishes) is not included in the list because none of the members could be identified to species.

TABLE 8

The most frequently observed fish species at Honolua Bay, Maui

Fish	Frequency	Total Number
1. *Thalassoma duperreyi*	1.000	821
2. *Eupomacentrus fasciolatus*	.846	774
Acanthurus nigrofuscus	.846	547
3. *Stethojulis balteata*	.731	138
Parupeneus multifasciatus	.731	78
Pervagor spilosoma	.731	76
4. *Gomphosus varius*	.654	59
Chaetodon unimaculatus	.654	52
5. *Acanthurus triostegus*	.615	178
Canthigaster janthinopterus	.615	47
		2,770

Fig. 13 The algal mat growing along the bottom of the inshore boulder habitat of Honolua Bay. Very little coral cover occurs in this habitat.

Fig. 14 The coral growth over the reef flat.

Fig. 15 The reef face at the edge of the reef flat which marks the beginning of the mid-channel sand/silt region.

The fishes were classified into three basic feeding groups according to Hiatt and Strasburg (1960) and Hobson (1974): herbivore, carnivore, and omnivore. (See Appendix 2.)

TABLE 9

Fish species most frequently seen along transect lines in Honolua Bay, Maui

A. Reef Face Habitat

SPECIES	RELATIVE ABUNDANCE INDEX
1. *Chromis leucurus*	.234
2. *Decapterus pinnulatus*	.215
3. *Eupomacentrus fasciolatus*	.088
4. *Thalassoma duperreyi*	.082
5. *Chromis ovalis*	.062

Total number of fish in habitat = 2,567.

This table is based on data from eight stations at four transects (3, 5, 9, and 15), located along the northern reef face and the point between Honolua and Makuleia Bays. Total number of species seen at transects: 59; mean number of individuals of all species per transect: 317. Total biomass ≈53.657 kg.

B. Reef Flat Habitat

SPECIES	RELATIVE ABUNDANCE INDEX
1. *Thalassoma duperreyi*	.169
2. *Acanthurus nigrofuscus*	.154
3. *Eupomacentrus fasciolatus*	.135
4. *Chromis leucurus*	.082
5. *Acanthurus triostegus*	.055

Total number of fish in habitat = 2,657.

This table is based on data from ten stations at five transects (6, 8, 12, 13, and 14) atop the fringing reefs of the bay. Total number of species seen at transects: 59; mean number of individuals of all species per transect: 231. Total biomass ≈67.134 kg.

C. Boulder Habitat

SPECIES	RELATIVE ABUNDANCE INDEX
1. *Eupomacentrus fasciolatus*	.212
2. *Chromis ovalis*	.176
3. *Thalassoma duperreyi*	.171
4. *Acanthurus nigrofuscus*	.078
5. *Stethojulis balteata*	.049

Total number of fish in habitat = 899.

This table is based on data from eight stations at four transects (7, 10, 11, and 16) along the smooth rock area at the back of the bay. Total number of species seen at transects: 41; mean number of individuals of all species per transect: 106. Total biomass ≈ 23.256 kg.

In the fish population, 63.8 percent (3,843 fishes) were carnivores, 32.5 percent (1,953) herbivores, and the remaining 3.7 percent (227 fishes) were omnivores. (See Fig. 16.) The total weight of fish in each feeding category was calculated (after Smith, 1949). The computed biomass* of the groups followed the same trend as the numbers of individuals of each group: 56.7 percent (89.93 kg) were carnivores, 37.1 percent (58.81 kg) herbivores, and 6.2 percent (9.72 kg) omnivores. (See Fig. 16.) An exceptionally high ratio of carnivores to herbivores (11:1) occurred at station 3.

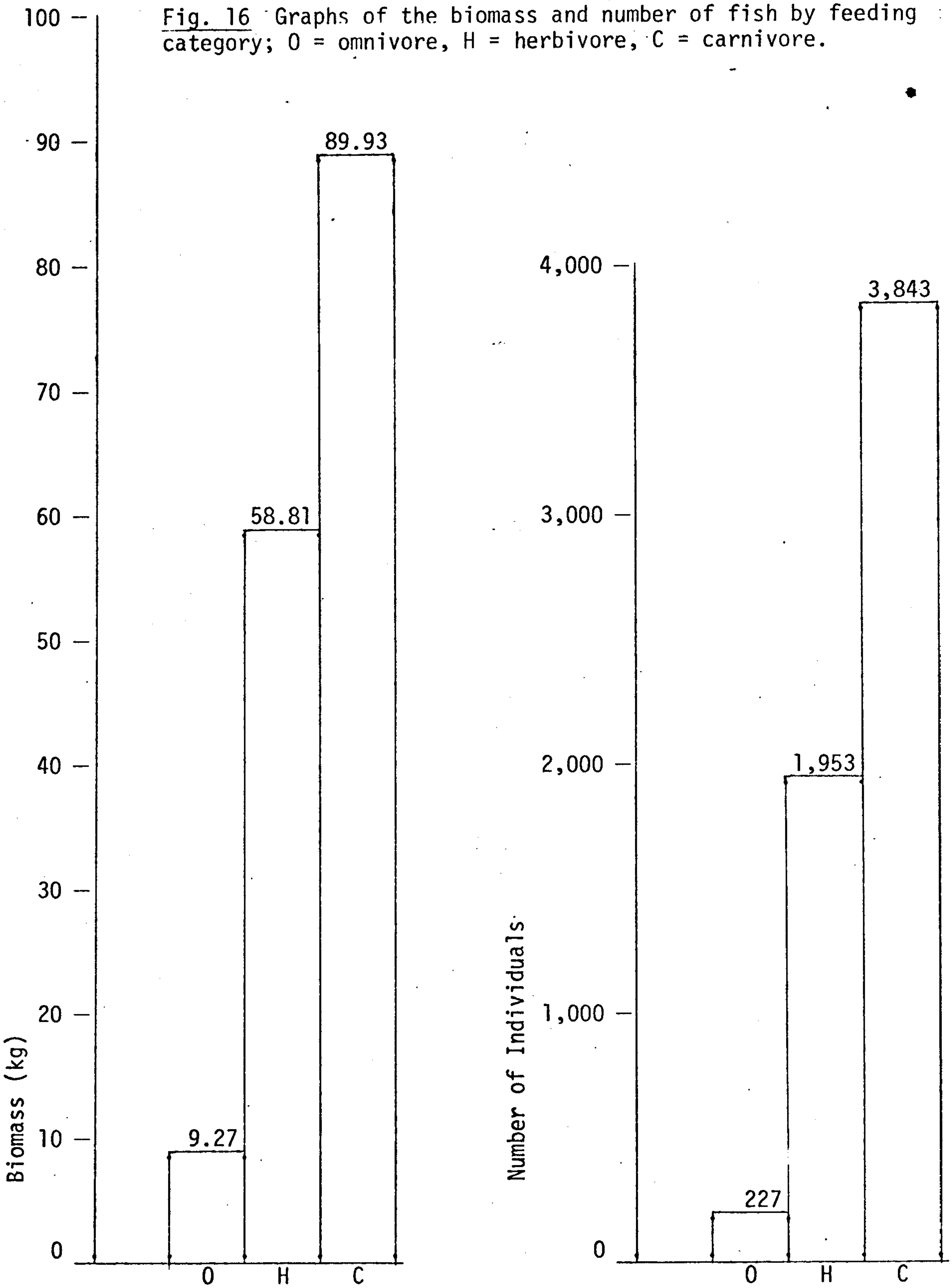
IV. DISCUSSION

A. Algae

The functions of algae in marine ecosystems do not make themselves easily apparent. As primary producers, they serve as a basis of food production and

*The family Scaridae is classified as herbivorous (Randall, 1967; and Hobson, 1974), but the biomass of the scarids could not be calculated because identification was not made to species.

Fig. 16 Graphs of the biomass and number of fish by feeding category; O = omnivore, H = herbivore, C = carnivore.



many calcareous forms contribute directly to reef building as well as provide sedimentation in reef environments (Smith, et al., 1973). They also provide major sources of organic matter in chiefly inorganic atoll soils (Doty, 1973). Any comprehensive study of a marine environment should include a census of the algae population because of its multifaceted role in marine ecosystems.

Coralline red algae, Jania sp. in particular, seem to prefer hard substrates and high energy environments (Smith et al., 1973). This probably explains the coralline red algae's abundance on the basalt shelves. However, crustose members of the family Corallinaceae and its fragile genera Jania sp. and Amphiroa sp. were observed under a layer of silt on boulders near shore in relatively calm waters. On many transects near shore, the observer had to "brush" a silt layer off the boulders to observe the algae. Interestingly, even with fresh water in the bay near shore, euryhaline genera such as Enteromorpha sp. or Ulva sp. were uncommon.

Competition for space between corals and algae (Maragos, 1972) seemed evident from tufts of filamentous algae growing on heads and between fingers of coral. Grazing pressure must certainly prevail with a fish population of 36.2 percent omnivores and herbivores and a noticeable sea urchin population, also herbivorous feeders (Dunlap, personal communication).

The Sorensen similarity test shows a fairly consistent cover composed of the dominant genera throughout the bay. (See Table 3.)

Generally, Honolua Bay showed a high proportion of a variety of red algae with a prevalence of encrusting and filamentous forms, an almost equal variety of green algae with light growths of filamentous greens on heads of live corals most apparent, and a handful of Phaeophyta consisting mainly of encrusting forms.

B. Substrate

In Honolua Bay, coral abundance was relatively low but with a high species diversity occurring in some areas. On the fringing basalt ledges, corals were consistently more abundant than in the areas comprised of the sand/silt channel that extends into the bay's head. Three important factors affected regional abundance and distribution of the reef corals in the bay: (1) substrate relief, (2) sedimentation, and (3) salinity.

Along the fringing basalt ledges, coral cover ranged from 36.4 percent to 20.9 percent, except for transects 14 and 15. On these two transects, coral cover was down to 15.9 percent and 3.6 percent respectively; this lower coverage was due to large sand pockets and large percentages of algal mat. Corals were much less abundant in these areas due to the competition for substrate by algae growth. The low coral abundance on the fringing reef shows a lack of dominance and a higher degree of species diversity on the basalt ledges (Maragos, 1972). Hermatypic corals were dominant along the reef slope. However, near the bottom of the slope both coral and algae cover dropped off sharply where sedimentation began.

The central sand/silt channel of the bay contained no live corals except where some hard substrate was found. (See Fig. 17.) The high porosity of the sediments and sand caused these areas to be unsuitable for coral attachment and growth. Transect 11 was conducted over the channel and yielded no live coral except where occasional hard substrate occurred. Near the bay's head, both the number of species and coral abundance dropped off markedly. This region consisted of an inner area of silt, sand, and boulders that maintained small colonies of live coral.

Fresh water seepage into the bay occurs near the mouth of Honolua Stream. There is a primary mixing zone between the stream's mouth and the first rock

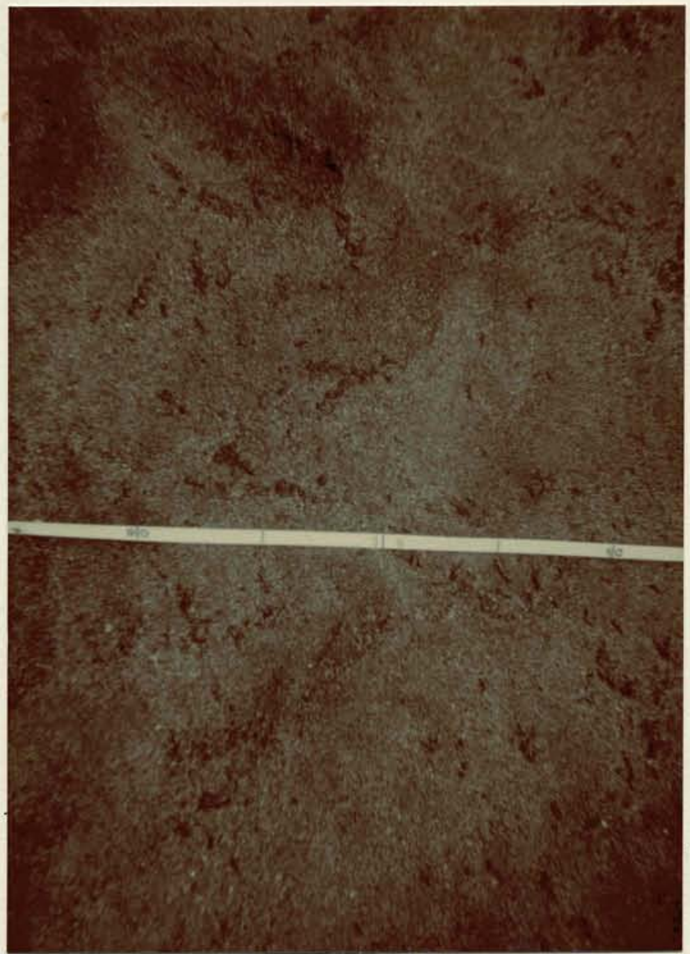


Fig. 17 The sand/silt substrate along the mid-channel of the bay.

outcrop of the southwest side of the bay (ECI, 1974). Within this area, transect 7 was carried out and the large percentage (34.7 percent) of hard bottom was probably due to the restriction of coral growth from low salinity levels.

Corals were most abundant on the fringing basalt ledges on the north and south sides of the bay. The higher percentages of Porites lobata on the reef flat suggests that this species thrived in areas subjected to heavy surge and salinity variations (Maragos, 1972).

The growth of Montipora verrucosa within certain areas of the bay showed that this species did best in shallow, low salinity areas of the bay. Maragos (1972) stated that M. verrucosa showed a high negative correlation to mean salinities and that variations in salinity appeared to stimulate its growth.

The branching growth form of Porites compressa enables it to dominate reef slope substrates. Like P. lobata, this coral appears dependent on water circulation factors and thrived in the outer portions of the bay.

Competition for space by other benthic organisms appeared to effectively regulate coral abundance (Maragos, 1972). Benthic algae damaged corals and inhibited their growth in some areas of the bay. On transect 14, large amounts of algae (93.9 percent) accounted for the low percentage of live coral (3.6 percent). Porites compressa is particularly vulnerable to attack because of the ideal lodging spaces for the algae between the finger-like branches of coral.

Maragos (1972) suggested that sediment inhibited growth, survival, and larval settlement of corals. At Honolua Bay's fringing reef slope, both coral and algae cover decreased where the sediment cover began. Data from transect 3 reinforced this statement because a sharp demarcation appeared as the transect went up the reef slope.

Currents, wave energy, and other circulation factors can affect coral growth in many ways: e.g., abrasion, mechanical stress, sediment accumulation, organic food supply, and variations in the physical properties of sea water (salinity, temperature). Environmental Consultants, Inc. (1974) indicated that Honolua Bay received constant clockwise flushing and the surface and sub-surface currents combined to flush nutrients over the reef areas. Also, ECI (1974) reported that wave action within the bay is minimal, but in periods of strong northerly swells, 3-4m waves break in the bay. (See Fig. 18.)

ECI (1974) documented that fresh water seepage caused variations in salinity (34-36 ppm) and temperature (25.5-27.0° C) throughout the bay. Within the bay these variables are controlled by local circulation patterns and may account for various zonations and distribution patterns of reef corals.

The distribution and growth of reef corals within Honolua Bay seem to be controlled by the interaction among certain factors: (1) substrate, (2) sedimentation, (3) salinity, and (4) circulation patterns.

Porites species were more common in areas that were richer in sediment (Maragos, 1972). It has been noted in other studies that Montipora sp. may be specifically adapted to slightly estuarine conditions and is able to do well where wave energy is high.

At the bay's head, coral growth and survival potential are greatly reduced due to lower salinities and to sedimentation.

C. Fish

A large population of 6,123 fishes was encountered at the study area. The presence of such a population with high diversity is the result of the various environmental conditions within the bay. The two fringing reefs, the boulders, and the reef flats offer an assortment of substrates for the fish.

Fig. 18 The long delicate spines of the sea urchin are a good indication of the calmness of the bay and the fresh water mixing which goes on in the bay.

Marshall (1952) and Randall (1963) contended that the greater part of fish fauna appeared to be associated with coral formations. Talbot (1965) demonstrated that an increase in the percentage and type of coral structures increases the quantity and complexity of the fish population. In Honolua Bay, a high coral cover occurs over the reef flats and the fringing reefs support the greatest quantity and diversity of fish in the bay. Along with coral, the benthic growth of the bay contains a large variety of encrusting and filamentous red and green algae. Acanthurids and scarids feed on the algae by scraping it off the substrate (Jones, 1968; Hobson, 1974). Bardach (1959) and Randall (1963) added that as well as providing increased shelter, the total surface area of the substrate is increased in areas of high coral density, which ultimately increases the niche size.

Ehrlich (1975) reported that much of the behavior of reef fishes seemed substrate-oriented because of strong predator pressure. Habitat selection for reef fishes became critical since food must be found in close proximity to suitable shelter. No live coral was present in the sand/silt channel of the bay and the region fronting the mouth of Honolua Stream. Stations in these areas contained a considerably smaller quantity of fish than the reef flats.

The largest quantity, as well as diversity, of fishes occurred at station 3. Included among the fish population were eleven cleaners, Labroides phthirophagus. This adds another "physical factor" to the list mentioned above. Labroides phthirophagus is an obligate cleaner, consuming mucus, scales, and dermal and epidermal tissues in addition to ectoparasites, and may supplement this cleaning diet with zooplankton (Youngbluth, 1968). Slobodkin and Fishelson (1974) have determined that the presence of cleaners created a high point diversity for the area near the cleaning station. Their study showed that large nonterritorial diurnal fish species of the reef, which made up one-fourth of the species of the reef, tended to congregate at cleaning stations. Thus, cleaners form a biological focus of diversity analogous to physical loci such as deep holes and areas of great geometric complexity.

None of the physical parameters mentioned above at station 3 are present at station 11, which resulted in the lowest fish count of all the monitoring stations. The station was located over the midbay sand/silt channel which provided no shelter. The few fishes observed on the transects were seen within the last 5m of the southern end of the transect line, at the foot of the southern fringing reef. Thus, the fish appear to be residents of the coral rubble habitat, not of the sand/silt habitat.

Thalassoma duperreyi proved to be the most abundant and most frequently seen fish species in the study site. Gosline and Brock (1960) stated that the genus *Thalassoma* is the largest genus of the largest family (Labridae) of Hawaiian reef fishes. They noted that *T. duperreyi* is probably the most common member of the genus and can be found in a variety of habitats from rocky substrate to reef flats. Hobson (1974) supported this by ranking *T. duperreyi* as high as second and no lower than sixth in his ten fish species most likely seen in the five major marine habitats along the Kona Coast.

The relative abundance indices of the fish species at each habitat (reef face, reef flat, and boulder) agree with the findings of Hobson (1974). The Honolua reef face habitat contains two species in the five most frequently seen fish species that Hobson considers to be associated with this type of habitat: *T. duperreyi* and *Eupomacentrus fasciolatus*. Hobson refers to the reef face habitat as having the greatest variety of fish. The Honolua reef face habitat is no exception. The reef flat and boulder habitats had three fish species, *Acanthurus nigrofuscus* (maiko), *E. fasciolatus*, and *T. duperreyi*, which coincided with Hobson's results.

The boulder habitat has a fish population composed of a large quantity of juveniles. ECI (1974) reported juveniles in the rounded rock bottom area near the stream mouth and dark sand beach on the west, and near the boat ramp and rock slide areas on the east. Along with the reef fish juveniles in the transect area, large schools of juvenile Chanos chanos (awa or milkfish) and Stolephorous purpureus (nehu) were careening just under the surface of the inshore waters. This supports the assumption that the inshore waters at the back of the bay act as nursery grounds for the reef fishes (ECI, 1974).

At Honolua Bay, the carnivore population outnumbered the herbivores by almost two and a half times. Hiatt and Strasburg (1960) suggested that it may be due to the carnivorous ancestry of modern fishes. Talbot (1965) added that from a carnivorous ancestry, the specializations needed for utilizing plant foods (long gut, methods of dealing with cellulose, use of plant protein) and the special carnivorous habit of coral feeding (coelenterates seem little exploited in most marine habitats, perhaps because of their nematocysts) have not often occurred. Talbot said that there are certainly fewer feeding niches available to herbivores and coral feeding fishes than to the remaining carnivores. Hiatt and Strasburg (1960) and Randall (1963) noted that of the impressive diversity of reef fishes, only a few groups are primarily herbivores.

The high carnivore to herbivore ratio of 11:1 at station 3 was attributed to the large number of planktivorous fish (500 Decapterus pinnulatus and 223 Chromis leucurus) at the station. According to Randall (1963), planktivorous fish are dependent upon the current to bring their food to them. Thus, if a reef is located in an area of adequate current and the water is rich in zooplankton, the reef will probably have a large population of such fish. A current enters Honolua Bay from the north along the northern reef face (ECI, 1974). It continues into the bay and moves in a clockwise fashion along the back of the bay. Then it returns to the ocean along the face of the southern fringing reef. The low visibility at station 3, which is positioned perpendicularly to the incoming current, may have been the result of a high zooplankton population.

The fringing reefs, which are isolated from each other by the mid-bay sand/ silt channel and the boulder habitat, have a biomass of carnivores that outweighs the herbivores by one and a half times. Bardach's work (1959) on an isolated Bermuda reef described a population of fish which had a biomass of carnivores twice as large as the omnivores: Randall (1963) states that Bardach's omnivores are really herbivores. Bardach adds that this data seems to contradict the classical concept of the biomass pyramid wherein the plant-feeders greatly predominate. He explains this discrepancy by pointing out that the largest fraction of herbivorous reef animals are probably mollusks, crustaceans, and annelids (echinoids should be added to the list, according to Randall, 1963). Bardach asserts that these invertebrates are the greatest source of food for the carnivorous reef fishes.

The work done on Tutia Reef by Talbot (1965) shows that this East African reef was comprised of 39 percent herbivores and 61 percent "carnivores" (the carnivores are made up by lumping carnivores and omnivores together). Honolua Bay has 37.1 percent hervivores and 62.9 percent "carnivores" (also consisting of carnivores and omnivores). Talbot concludes that this reef is typical of an outer reef community.

Comparison of the biomass of the three feeding categories of Honolua Bay with the natural reef fish population of St. John of the Virgin Islands (Randall, 1963) showed that Honolua has a higher percentage of herbivores and a lower percentage of carnivores and omnivores. It may indicate that Honolua has a greater marine floral production as a food component than the St. John reef or that less food is available outside the reef habitat at St. John. The discrepancy could also be the result of the use of two separate methods to count the reef fishes. The method applied at Honolua did not allow the transecters to investigate cracks and crevices along the reef for fishes. This cuts down the number of carnivores which live the majority, if not all, of their lives within the reef (such as apogonids, holocentrids, muraenids, and scorpaenids). Randall used rotenone poison which produced a more complete collection of species on and in the reef. This would not be practical at Honolua. Another factor that must be taken into consideration is the period in the day the transects were undertaken at Honolua. Collete and Talbot (1972) and Hobson (1972) have reported that most reef fishes are more active during the early morning and late evening hours. Time is not a major factor when poisoning is the primary method of collecting data. The Honolua Bay transects were all run between 8:00 a.m. and 4:30 p.m.

Conclusion

Honolua Bay consists of a variety of marine environments, which support two coral reef communities. The reef fish population of the northern and southern fringing reefs is abundant and diverse. The reef fish population may be looked upon as a typical, isolated, outer reef assemblage. The authors support the recommendation by Dr. Leighton Taylor that the bay be designated as a marine conservation district so that the diversity and abundance of fishes will increase, as was the case with Hanauma Bay, Oahu. Randall (1963) and Taylor (1975) recognized the importance of exploitation by fisherman on the standing crop of reef fishes. Taylor (1975) and the researchers in this study encountered spear-fishermen in the study site. In the presence of the transecters, the reef fishes tended to swim off quickly, especially the large edible fishes: Acanthurus dussumieri (palani), Naso unicornis (kala), Mulloidichthys flavolineata (weke 'ula), and members from the family Scaridae (uhus and parrotfishes). This corroborates the conclusion by Kitahata and McCreary (1975) that the fish inhabiting Honolua Bay are extremely wary of divers and snorkelers.

V. ACKNOWLEDGMENTS

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VI. APPENDICES

Appendix 1

List of fish species with their biomass and the site of occurrence.
1 = fish seen on one station; 2 = fish seen on both stations of same transect.

NAME	3	5	6	7	8	9	10	11	12	13	14	15	16	FREQUENCY	TOTAL BIOMASS (kg)
ACANTHURIDAE															
Acanthurus dussumieri							1			1				.077	2.948
Acanthurus leucopareius			1	1		2	1			2	2			.269	2.834
Acanthurus nigrofuscus	2	2	2	2	2	2	2		2	1	2	2	1	.846	26.21
Acanthurus nigroris			1	2					1					.154	0.310
Acanthurus olivaceus	1													.038	0.077
Acanthurus triostegus	2		2	2	1	2	2		1	1	2		1	.615	7.413
Acanthurus xanthopterus		1												.038	0.113
Ctenochaetus strigosus	2				2	1	1		1	2				.346	1.598
Naso lituratus				1						1	1			.115	1.018
Naso unicornis	1	1	1						1	1				.192	2.196
Zanclus canescens				2	1	1				1				.192	0.460
Zebrasoma flavescens	2					2				2				.231	0.122
APOGONIDAE															
Apogon menesemus										1				.038	0.032
AULOSTOMIDAE															
Aulostomus chinensis	2					2			1					.192	0.081

NAME	3	5	6	7	8	9	10	11	12	13	14	15	16	FREQUENCY	TOTAL BIOMASS (kg)
BALISTIDAE															
Pervagor spilosoma	2	2	1	1	2	2	1		2	2	1	1	2	.731	1.171
Rhinecanthus rectangulus	2		2	1	2		1		1	1	2	1	1	.538	4.418
Sufflamen bursa	2	2				2				1				.269	1.426
BLENNIIDAE spp. undetermined											2			.077	--
Exaliias brevis										1				.038	0.058
CARANGIDAE spp. undetermined						1								.038	--
Caranx melampygus												1		.038	0.257
Decapterus pinnulatus	1				1	1						1		.154	2.453
Trachurops crumenophthalmus						1								.038	0.538
CHAETODONTIDAE															
Centropyge potteri	2	1								2				.192	1.066
Chaetodon auriga					1	1							1	.115	0.282
Chaetodon fremblii	2	2	1	1			1					2	1	.384	.272
Chaetodon kleini											1			.038	0.083
Chaetodon lunula						1			1					.077	0.554
Chaetodon miliaris		1				2						1		.231	0.60
Chaetodon multicinctus	1	1	1		2				2					.269	0.531
Chaetodon ornatissimus			1											.038	0.262
Chaetodon quadrimaculatus	1		1										1	.115	0.219
Chaetodon trifasciatus					2	1						1		.154	0.79
Chaetodon unimaculatus	1		2	1	2	2			2	2	1	2	2	.654	1.446

NAME	3	5	6	7	8	9	10	11	12	13	14	15	16	FREQUENCY	TOTAL BIOMASS (kg)
CIRRHITIDAE															
Cirrhitops fasciatus	2				2				2	2				.308	0.567
Cirrhitus pinnulatus		1			2			1						.154	0.20
Paracirrhites arcatus	2		2	1					2	2				.346	0.798
Paracirrhites forsteri	1		1							1				.115	0.468
DIODONTIDAE															
Diodon hystrix						1								.038	0.560
FISTULARIIDAE															
Fistularia petimba	1			1	1		1					1	1	.231	0.189
HOLOCENTRIDAE spp. undetermined	1									1				.077	--
Myripristis murdjan	1					1								.077	0.092
KYPHOSIDAE															
Microcanthus strigatus						1								.038	*
LABRIDAE spp. undetermined	1									1	2			.154	--
Anampses chrysocephalus										1				.038	0.068
Anampses cuvieri				2						1				.115	1.617
Bodianus bilunulatus	1				2									.115	0.492
Cheilinus rhodochrous			2							1				.115	0.217
Cheilio inermis								1						.038	0.011
Coris gaimardi	1	1												.077	0.065
Coris venusta											1		2	.115	0.121
Gomphosus varius	2		2	2	2	1			2	2	2	2		.654	0.950

*Constant for determining biomass not available.

NAME	3	5	6	7	8	9	10	11	12	13	14	15	16	FREQUENCY	TOTAL BIOMASS (kg)
Halichoeres ornatissimus	1		1	2						2				.231	0.347
Labroides phthirophagus	2								1	2				.192	0.138
Macropharyngodon geoffroyi				1					1	1				.115	0.620
Stethojulis balteata	1	1		2	2	2	2		2	2	2	1	2	.731	1.649
Thalassoma ballieui	1													.038	0.174
Thalassoma duperreyi	2	2	2	2	2	2	2	2	2	2	2	2	2	1.000	26.267
Thalassoma purpureum	1			1										.077	0.099
MULLIDAE															
Mulloidichthys flavolineata						2								.077	7.502
Mulloidichthys vanicolensis				2	1	2				2			1	.308	5.409
Parupeneus bifasciatus				1					1	1				.115	0.363
Parupeneus chryserydros									1					.038	0.015
Parupeneus multifasciatus	2	2	1	2	2	1	2		2	2	2		1	.731	5.719
Parupeneus pleurostigma	2	1	1			2	2						1	.346	2.257
Parupeneus porphyreus					1	2	2		1				2	.308	2.505
MURAENIDAE spp. undetermined											1			.038	--
Gymnothorax flavimarginatus													1	.038	0.489
OSTRACIONTIDAE															
Ostracion meleagris						1					1	1		.115	0.102
POMACENTRIDAE spp. undetermined			2	1					1	1				.192	--
Abudefduf abdominalis	2					2	1			2			2	.346	3.913
Abudefduf sindonis	1													.038	*

*Constant for determining biomass not available.

NAME	3	5	6	7	8	9	10	11	12	13	14	15	16	FREQUENCY	TOTAL BIOMASS (kg)
Chromis leucurus	2	1	1			2		1	2	2	1	2		.538	6.961
Chromis ovalis	2	2				1	1		2	1	2		2	.500	8.501
Chromis vanderbilti	2					2	1				1	2		.308	0.347
Dascyllus albisella		2										1		.115	0.050
Eupomacentrus fasciolatus	2	2	2	2	2	2	2		2	2		2	2	.846	16.965
Plectroglyphidodon imparipennis	2										2	1		.192	0.022
Plectroglyphidodon johnstonianus	1	1				2					2			.231	0.263
SCARIDAE spp. undetermined	2	1	2	2	2	1			2	1	2		2	.654	--
TETRAODONTIDAE															
Canthigaster amboinensis					1	1						1	1	.115	0.119
Canthigaster coronatus				1					1	1				.115	0.120
Canthigaster janthinopterus	2	2	1		1	1	1	2	1	2	1	1	1	.615	0.488

Total number of species in study: 76 species

Total number of species (this does not include Mr. Gaffney's identification of *Acanthurus sandvicensis*, believed to be *A. triostegus*, and Chaetodon clown, which is not a species name) in all four surveys: 95 species

APPENDIX 2

List of fish with their common names and feeding type. C = carnivore; H = herbivore; O = omnivore

SCIENTIFIC NAME	COMMON NAME	FEEDING TYPE
ACANTHURIDAE	Surgeonfishes, Tangs	
Acanthurus dussumieri	palani	O
Acanthurus leucopareius	maiko	H
Acanthurus nigrofuscus	mai'i	H
Acanthurus nigroris	maiko	H
Acanthurus olivaceus	na'ena'e	H
Acanthurus triostegus	manini, convict tang	H
Acanthurus xanthopterus	pualu	H
Ctenochaetus strigosus	kole	H
Naso lituratus	kala, clown tang	H
Naso unicornis	kala, unicornfish	H
Zanclus canescens	kihikihi, Moorish Idol	C
Zebrasoma flavescens	la-'i-pala, yellow tang	H
APOGONIDAE	Cardinalfishes, Moonshine Annie	
Apogon menesemus	'upapalu, Moonshine Annie	C
AULOSTOMIDAE	Trumpetfish	
Aulostomus chinensis	nūnū	C
BALISTIDAE	Triggerfishes and Filefishes	
Pervagor spilosoma	'o'ili uwiuwi, orangetail filefish	O
Rhinecanthus rectangulus	humuhumu-nukunuku-a-pua'a	O

SCIENTIFIC NAME	COMMON NAME	FEEDING TYPE
Sufflamen bursa	humuhumu-umauma-lei	C
BLENNIIDAE	Blennies	
Blennid sp.		
Exalias brevis	pao'o kauila, 'o'opu pao'o	C
CARANGIDAE	Uluas, papios, jacks, crevallies	
Carangid sp.		
Caranyx melampygus	omilu	C
Decapterus pinnulatus	opelu	C
Trachurops crumenophthalmus	akule, halalu, Aji	C
CHAETODONTIDAE	Butterflyfishes	
Centropyge potteri	Potter's Angle	O
Chaetodon auriga	threadfin butterflyfish	C
Chaetodon fremblii	blue-stripe butterflyfish	C
Chaetodon kleini		C
Chaetodon lunula	kikakapu, masked/raccoon butterflyfish	C
Chaetodon miliaris	lemon butterflyfish	C
Chaetodon multicinctus	pebble butterflyfish	C
Chaetodon ornatissimus	kikakapu, ornate butterflyfish	C
Chaetodon quadrimaculatus	four-spot butterflyfish	C
Chaetodon trifasciatus		C
Chaetodon unimaculatus	kikakapu, one spot/tear-drop butterflyfish	C
CIRRHITIDAE	Hawkfishes	
Cirrhitops fasciatus	piliko'a	C

SCIENTIFIC NAME	COMMON NAME	FEEDING TYPE
Cirrhitus pinnulatus	po'o-paa, 'o'opu-kai	C
Paracirrhites arcatus	piliko'a	C
Paracirrhites forsteri	hilu piliko'a, piliko'a	C
DIODONTIDAE	Spiny Puffers	
Diodon hystrix	'o'opu-kawa	O
FISTULARIIDAE	Cornetfish	
Fistularia petimba	Cornetfish	C
HOLOCENTRIDAE	Soldierfish and Squirrelfishes	
Holocentrid sp.		
Myripristis murdjan	u'u menpachi	C
KYPHOSIDAE	Rudderfishes	
Microcanthus strigatus	stripey, convictfish	O
LABRIDAE	Wrasses, hinalea	
Labrid sp.		
Anampses chrysocephalus		C
Anampses cuvieri	snowflake wrasse, Uncle Sam wrasse	C
Bodianus bilunulatus	a'awa, table boss	C
Cheilinus rhodochrous	po'ou	C
Cheilio inermis	kupou'pou, cigar wrasse	C
Coris gaimardi	lolo	C
Coris venusta		C
Gomphosus varius	'aki-lolo, hinalea i'iwi, bird wrasse	C
Halichoeres ornatissimus	la'o, 'ohua, pa'awela, christmass tree wrasse	C
Labroides phthirophagus	cleaner wrasse	C

SCIENTIFIC NAME	COMMON NAME	FEEDING TYPE
Macropharyngodon geoffroyi	Potter's wrasse	C
Stethojulis balteata	'omaka	C
Thalassoma ballieui	hinalea lauhine, mongoose wrasse	C
Thalassoma duperreyi	hinalea lauwili, 'a'ala'ihi	C
Thalassoma purpureum	'olami, 'olali, palae'a, 'awela	C
MULLIDAE	Goatfishes	
Mulloidichthys flavolineata	weke-'ula	C
Mulloidichthys vanicolensis	weke-'a'a, spot weke	C
Parupeneus bifasciatus	munu	C
Parupeneus chryserydros	moano kea, moana kali	C
Parupeneus multifasciatus	moana, moano	C
Parupeneus pleurostigma	malu	C
Parupeneus porphyreus	kumu	C
MURAENIDAE	Moray Eels	
Muraenid sp.		
Gymnothorax flavimarginatus	puhi-paka	C
OSTRACIONTIDAE	Boxfishes and Cowfishes	
Ostracion meleagris	moa, mamoa, waa, oopakuku	C
POMACENTRIDAE	Damselfish	
Pomacentrid sp.		
Abudefduf abdominalis	maomao, mamo, sergant major	C
Abudefduf sindonis	black mamo	C
Chromis leucurus		C

SCIENTIFIC NAME	COMMON NAME	FEEDING TYPE
Chromis ovalis		C
Chromis vanderbilti		C
Dascyllus albisella	aloiloi, three-spot damselfish	C
Eupomacentrus fasciolatus		C
Plectroglyphidodon imparipennis		C
Plectroglyphidodon johnstonianus		C
SCARIDAE	Uhu, Parrotfish	
Scarid spp.		
TETRAODONTIDAE	Puffers	
Canthigaster amboinensis	pu'u-ola'i	O
Canthigaster coronatus		O
Canthigaster janthinopterus		O

APPENDIX 3

Supplementary Information

Three additional monitoring sites were established outside the study site to obtain some information on the outer areas. Site 1 was located at the southern end of the sandy beach of Makuleia Bay. Site 4 was situated offshore of this sandy beach; site 2 was located along the north end of the mouth of Honolua Bay (see Fig. 1 and Table 1).

Outside the confines of the bay (sites 1, 2, and 4), there was relatively more coral growth and diversity than most of the transects done within the bay. These outer transects showed a high percentage of coral cover except in site 4 which occurred entirely over sand.

The stations at site 1 ran along the ledge of a basalt flat, which has several sand channels cutting perpendicularly to the shoreline into the flat. The substrate on the ocean side of the ledge consists entirely of sand. A slight current ran from north to south along the ledge. Bottom surge was evident over the basalt flat. An average of 243 fishes representing 29 species was observed on the transects performed at the stations. Two more fish species were seen at this site than at the Honolua Bay sites: the chaetodontid Forcipiger flavissimus (lau-wiliwili-nukunuku-'oi'oi or long-nosed butterflyfish) and a pomacentrid, Chromis verater (black damselfish). The average biomass of the transects was 3.197 kg.

Site 4 was located on a substrate composed completely of sand. A slight bottom surge was present during the transects. No fish were present at the site. However, a large school of Decapterus pinnulatus (approximately 1,000), herded by several large carangids, including a Seriola dumerili (kahala, about 1.1m long) and a school of about 20 Thunnus albacares (ahi, about 0.6m in length) were sighted on the survey dive the previous day. Also, in the immediate area of the site several Euthynnus yaito (kawakawa) were entangled in a lay net. The depth at the site was 10.7m and the visibility was 15.2m.

Similar environmental conditions existed at site 2. An average of 328 individuals representing 39 species with an average biomass of 5.333kg was seen on the transects at site 2. Outside the transect area several large Scarus perspicillatus (uhus, about 61cm in length) were seen along the outer ledge; a school of Myripristis murdjan (menpachi) were huddled in the crevices of the ledge. The depth at the site ranges from 6.1m to 9.1m, and visibility was between 9.1m and 12.2m.

In conclusion, the area in front of Makuleia Bay is composed of a sandy substrate without a resident fish population, except for schools of passing pelagic fishes. Sites 1 and 2 had similar habitats, which resembled the reef flat habitat at Honolua Bay. In addition, site 2 indicated that the reef fish population of the bay continued out onto the northern coastline of the entrance of Honolua Bay. The sandy substratum to the south of Honolua Bay isolated that reef from the Makuleia Bay basalt flat. Thus, the Honolua reef is separated from the rest of the coastline to the south of the bay.

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